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Ontario Geological Survey
Open File Report 6143

Georgian Bay Geological Synthesis, Grenville Province: Explanatory Notes for Preliminary Maps P.3548 to P.3552

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Georgian Bay Geological Synthesis, Grenville Province: Explanatory Notes for Preliminary Maps P.3548 to P.3552

by

N.G. Culshaw, D. Corrigan, J.W.F. Ketchum, P. Wallace, N. Wodicka and R.M. Easton

2004

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Abstract

The Grenville Orogen formed during collision of the Laurentian margin and related terranes with an unknown, presumably continental, plate. The Central Gneiss Belt, together with the Grenville Front tectonic zone, forms the structurally lowest part of the Grenville Orogen in central Ontario. Metamorphism, deformation and minor magmatism related to the collision and convergence that formed the Grenville Orogen are recorded in the Central Gneiss Belt during the interval 1160 to 1000 Ma.

Essentially, the Central Gneiss Belt consists of a stack of gently-dipping gneissic units (domains) each of which has a distinctive lithological make-up, age of formation, and plutonic and metamorphic history. On account of the highly strained nature of some of the domain boundaries and the evident differences in pre-Grenville history of neighbouring domains, the domains have been interpreted as thrust sheets. Structurally lower domains (polycyclic domains) contain evidence for a pre-Grenville metamorphism, the overlying units (monocyclic domains) do not. The boundary separating the polycyclic and monocyclic domains is termed the Allochthon Boundary Thrust. Several of the domains are made up of subgroupings of consistently associated rock types known as gneiss associations. These components of the domains are not usually separated by structures interpreted as thrusts, and their assembly within the domains therefore predates thrust stacking of domains. Two features of the geology of the Central Gneiss Belt are of special interest:

1. Because metamorphic grade is uniformly upper amphibolite facies or higher the Central Gneiss Belt gives an unrivalled view of processes at mid-depth of a doubly thickened orogenic crust.
2. The similarity of ages and rocks types of the Central Gneiss Belt with those of the Central Plains, Eastern Granite-Rhyolite Province and some southwest USA terranes has long been recognized. Thus, together with these terranes, and much of the Grenville to the northeast, the Central Gneiss Belt was part of a huge active continental margin formed during the Paleo- and Mesoproterozoic. The well-exposed rocks of the Central Gneiss Belt offer insight into the development of this margin before the Grenville Orogen formed.

Georgian Bay Geological Synthesis, Grenville Province: Explanatory Notes for Preliminary Maps P.3548 to P.3552

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Introduction

This report is designed to provide additional information with respect to the content and design of Ontario Geological Survey Preliminary Maps P.3548 to P.3552 (Culshaw et al. 2004a-e, back pocket), which provide geological coverage of roughly 140 km of Georgian Bay shoreline from Key Harbour to Port Severn (Figure 1).

The mapping results described in this report and on the aforementioned maps were collected as part of a 3-year mapping program, Project C.2.3, Georgian Bay Geological Synthesis, funded as part of the five-year Canada–Ontario 1985 Mineral Development Agreement (COMDA), a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario. The project was carried out in contract with the Geological Survey of Canada. Preliminary results were published by Culshaw et al. (1988, 1989, 1990). Final publication of the maps (Ontario Geological Survey Project 03-006) was assumed by the Ontario Geological Survey in 2003, by mutual agreement with the Geological Survey of Canada.

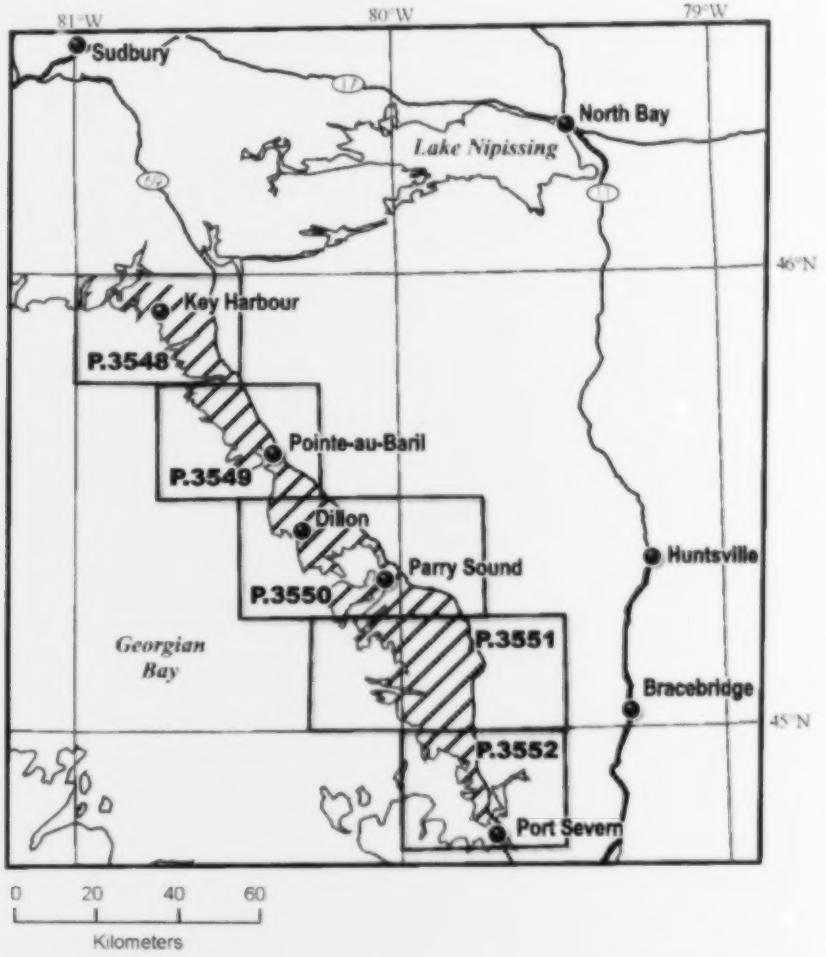

Figure 1. Location of the Georgian Bay geological transect and map areas covered by this study.

OVERVIEW

The Grenville Province (or Grenville Orogen) was among the first parts of the Canadian Shield mapped in Canada (Logan 1863, 1866), and the first discovery of gold in Ontario was made near Eldorado in 1866. Considerable mapping was done in the Grenville Province in the late 19th century (e.g., Adams and Barlow 1910), and study of the Grenville Province in Ontario contributed to many geologic concepts of the time (Easton 1992). However, as the area became more populated and significant mineral finds were made in northern Ontario, the economic impetus for geologic fieldwork in the Grenville Province diminished. It also soon became apparent that the geology of the Grenville Province was complex. This complexity discouraged many workers, and it is only recently that the study of Precambrian orogenic belts has advanced to the point that we can now begin to unravel the geology of the Grenville Province and to make meaningful comparisons with modern orogens.

The most complete recent summary of the Grenville Province in Ontario is that of Easton (1992). Easton and Fyon (1992) and Carter (1984) have provided overviews of the metallogeny of the Grenville Province in Ontario.

Regional Setting of the Grenville Province in North America

To understand the Grenville Province in Ontario, one must first place it in a regional tectonic setting. Major geologic regions in the midcontinent of central North America are the Southern Province, the Penokean Orogen, the Killarney Magmatic Belt, the Eastern Granite-Rhyolite Province, the Midcontinent Rift System, and the Grenville Province.

Metasedimentary and minor metavolcanic rocks of the Huronian Supergroup of the Southern Province underlie the southernmost Canadian Shield between Sault Ste. Marie and the Ottawa River (Bennett, Dressler and Robertson 1991). These rocks were folded and metamorphosed during the circa 1835 Ma Penokean Orogeny (Bickford, Van Schmus and Zeitz 1986). The Huronian rocks southeast of Sudbury are separated from the Grenville Front by plutonic and lesser volcanic rocks of the Killarney Magmatic Belt (van Breemen and Davidson 1988), exposed along an 80 km stretch of the front along Georgian Bay near Killarney, Ontario. These rocks intrude the Huronian Supergroup, and yield U/Pb ages 1750 to 1730 Ma and 1470 to 1450 Ma (van Breemen and Davidson 1988). Southeast of the Grenville Front, Killarney Magmatic Belt rocks have been affected by the Grenville Orogeny. The Killarney granitoids have been interpreted (Easton 1986; van Breemen and Davidson 1988) to be an extension of one of several Mesoproterozoic orogenic belts underlying much of the North American midcontinent west of Ontario. As the northern limit of the Grenville Province is considered to be the Grenville Front, the Killarney Magmatic Belt north of the Grenville Front is not part of the Grenville Province (e.g., Easton 1992).

Felsic volcanic rocks and associated plutons of the Eastern Granite-Rhyolite Province form much of the basement beneath the midcontinental United States west of the Grenville Front in southern Michigan, Ohio, and Indiana. These rocks were emplaced between 1480 to 1420 Ma and circa 1350 Ma (Bickford, Van Schmus and Zeitz 1986). Cutting this province is a northwesterly trending belt of gravity and aeromagnetic anomalies interpreted to represent the buried portion of the 1100 Ma Midcontinent Rift (Sutcliffe 1991).

The Grenville Front marks the northwest limit of penetrative Grenvillian metamorphism and deformation and truncates structural trends in the adjacent structural provinces, although locally some of these rocks can be traced across the Grenville Front for short distances (10 to 30 km, Easton 1992). It is now generally accepted that this orogenic event (or events) involved northwest-directed thrusting and imbrication of the entire crust, presumably as a result of a terminal collision at about 1100 Ma with a

continental landmass somewhere to the southeast (e.g., Rivers et al. 1989; Carr et al. 2000). Many Rb/Sr and K/Ar ages in the Grenville Province range from 1000 to 950 Ma, synchronous with cooling after the Grenville Orogeny. For the rocks exposed in the Grenville Province this paper uses major subdivisions as originally proposed by Wynne-Edwards (1972), as revised by Easton (1992) (*see* Figure 2).

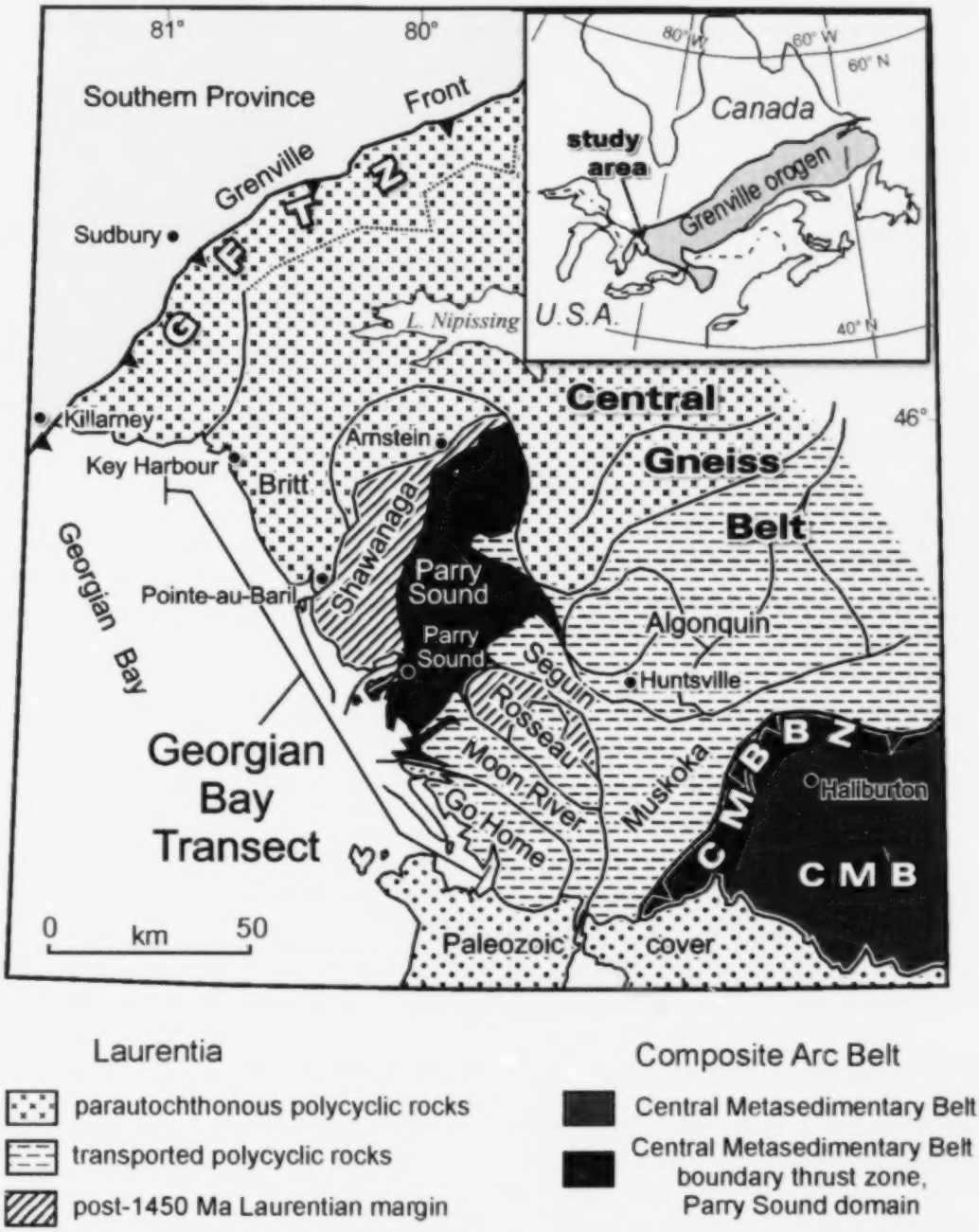

Figure 2. Location of Central Gneiss Belt; domains are named. Georgian Bay transect refers both to the area of shoreline covered by this study, as well as the location of the cross-section shown in Figure 3. Abbreviations: GFTZ, Grenville Front tectonic zone; CMBBZ, Central Metasedimentary Belt boundary zone; CMB, Central Metasedimentary Belt.

Subdivisions of the Grenville Province

Over the past 40 years, several approaches have been used to subdivide the Grenville Province into lithologic and/or tectonic entities. The subdivision of the Grenville used here (Figure 2) has drawn from several previous subdivisions in particular, Wynne-Edwards (1972), Davidson, Culshaw and Nadeau (1982), and Easton (1992).

The Grenville Province in Ontario consists of 2 main divisions: the Central Gneiss Belt and the Central Metasedimentary Belt (*see* Figure 2) (Wynne-Edwards 1972). The Grenville Front separates the Grenville Province from older units to the north and northwest. That part of the Central Gneiss Belt that lies within 20 to 30 km of the Grenville Front has been termed the Grenville Front tectonic zone (e.g., Wynne-Edwards 1972; Rivers et al. 1989). The zone consists of deformed and metamorphosed rocks derived from the Southern and Superior Provinces and the Killarney Magmatic Belt and is characterized by northeast-trending zones of cataclasis, northeast-trending foliations, and by a prominent southeast-plunging lineation (Easton 1992).

The Grenville Front tectonic zone, which includes the Grenville Front Boundary Fault, and the Central Metasedimentary Belt boundary zone, which separates the Central Gneiss Belt from the Central Metasedsimentary Belt (see Figure 2), are major shear zones several kilometres in width, characterized by strongly deformed rocks with northeasterly trending, moderately to shallowly southeast-dipping tectonic layering, and southeast-plunging mineral lineations. Mylonites are locally developed. Marble tectonic breccia, containing fragments of metasedimentary, plutonic, and amphibolite rocks is common within, and adjacent to the eastern margin of the Central Metasedimentary Belt boundary zone. Significantly the 2 zones are subparallel in Ontario (*see* Figure 2). Similar subparallel zones of intense deformation on a smaller scale form boundaries between lithotectonic terranes and domains within both the Central Gneiss Belt and the Central Metasedimentary Belt (*see* Figure 2).

The Central Gneiss Belt and parts of the Central Metasedimentary Belt boundary zone, consist mainly of quartzofeldspathic gneissic rocks that have generally been metamorphosed to upper amphibolite facies, and locally to granulite facies. Most of these gneisses are believed to be plutonic in origin, with subordinate amounts of metasedimentary gneiss. In Ontario, the dominant structures and foliations in these rocks are northeasterly, and these trends are very evident on aeromagnetic maps of the area. The Central Gneiss Belt consists of a variety of Archean to Mesoproterozoic crustal segments, all of which have been affected by the Grenville Orogeny (Easton 1986, 1992). Crustal material of 3 main ages is present (Easton 1986, 1992; Dickin and McNutt 1989). North of the French River, reworked Archean and Paleoproterozoic gneisses are intruded by Mesoproterozoic (1250 to 1500 Ma) plutonic rocks, with granitic and monzonitic rocks predominant. The bulk of the Central Gneiss Belt consists of Mesoproterozoic gneisses (1600 to 1800 Ma) intruded by 1400 to 1500 Ma granitic and monzonitic plutons. The Parry Sound domain (*see* Figure 2) consists of mafic to intermediate composition rocks formed from at about 1350 to 1450 Ma (Dickin and McNutt 1989; Wodicka, Parrish and Jamieson 1996).

Distinctive lithotectonic terranes, some further subdivided into domains, have been identified with the Central Gneiss Belt (e.g., Culshaw, Davidson and Nadeau 1983; Easton 1992) (*see* Figure 2). The terranes and domains are distinguished by differences in their rock assemblages, internal structure, metamorphic grade, and locally by geophysical signature. They are bounded by zones of intensely deformed and sheared rocks characterized by layering that can be traced for many tens of kilometres. The Central Gneiss Belt is described in greater detail in the next section of the report.

The Central Metasedimentary Belt lies southeast of the Central Gneiss Belt (*see* Figure 2), and is a major Mesoproterozoic accumulation of metavolcanic and siliciclastic and carbonate metasedimentary

rocks. The supracrustal rocks comprise the classical Grenville Supergroup, which consists of a variety of formations and groups, as outlined in Easton (1992). The supracrustal rocks have been invaded by a variety of compositionally diverse syntectonic, late-tectonic, and post-tectonic plutonic rocks, and the entire succession has been metamorphosed at grades ranging from greenschist to granulite facies. The Central Metasedimentary Belt can be divided into several lithotectonic terranes characterized by differences in lithology, geologic history, structural history, and ages of metamorphism and plutonism (e.g., Easton 1992). The Elzevir and Bancroft Terranes, which include the Grenville Supergroup, are characterized by volcanism and sedimentation between 1300 and 1250 Ma, followed by plutonism and metamorphism at 1240 to 1250 Ma and again at 1100 to 1070 Ma. In contrast, the Frontenac Terrane lacks volcanic rocks, and was subjected to plutonism and metamorphism at roughly 1170 to 1160 Ma.

CENTRAL GNEISS BELT

The Grenville Orogen formed during collision of the Laurentian margin and related terranes with an unknown, presumably continental, plate. The Central Gneiss Belt (CGB), together with the Grenville Front tectonic zone, forms the structurally lowest part of the Grenville Orogen in central Ontario. Metamorphism, deformation and minor magmatism related to the collision and convergence that formed the Grenville Orogen are recorded in the Central Gneiss Belt during the interval 1160 to 1000 Ma (see Culshaw et al. (1997) and Carr et al. (2000) for further details).

Essentially, the Central Gneiss Belt consists of a stack of gently dipping gneissic units (domains) each of which has a distinctive lithological make-up, age of formation, and plutonic and metamorphic history. On account of the highly strained nature of some of the domain boundaries and the evident differences in pre-Grenville history of neighbouring domains, the domains have been interpreted as thrust sheets. Structurally lower domains (polycyclic domains) contain evidence for a pre-Grenville metamorphism, the overlying units (monocyclic domains) do not (*see* Figure 2). The boundary separating the polycyclic and monocyclic domains is termed the Allochthon Boundary Thrust (Rivers et al. 1989; Ketchum and Davidson 2000). Several of the domains are made up of subgroupings of consistently associated rock types known as gneiss associations. These components of the domains are not usually separated by structures interpreted as thrusts and their assembly within the domains therefore predates thrust stacking of domains. Two features of the geology of the Central Gneiss Belt are of special interest:

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PREVIOUS WORK

A traverse of the shore of Georgian Bay was made by Alexander Murray in 1848 (Murray 1850, p.45 to 46), and again by Robert Bell in 1876 (Bell 1878, p.198 to 207). The International Geological Congress had a field excursion in the Parry Sound area in 1913, and examined some localities on Parry Island (Walker 1913, p.98 to 100). Most previous work in the study area has focussed on the immediate area surrounding Parry Sound, with Coleman (1894, p.98 to 100; Coleman 1899, p.259 to 260), Satterly (1943) and Hewitt (1967) describing the geology and mineral occurrences of the Parry Sound area. More

recently, the Ontario Geological Survey published a series of 1:50 000 scale compilation maps for the Muskoka domain and its environs (Lumbers and Vertolli 2000a-g). Of this series of maps, 3 sheets, 31D/13, 31E/4 and 31E/5 (Lumbers and Vertolli 2000c, 2000e, 2000g) overlap with parts of maps P.3550, P.3551 and P.3552 (*see* back pocket).

Regional geological mapping of the western Central Gneiss Belt in Ontario by Davidson, Culshaw and Nadeau (1982) and Culshaw, Davidson and Nadeau (1983) led to the recognition of the tectonic significance of regional high-strain zones in the area, and established the basic tectonic framework of terranes and domains that is utilized in this report (*see* Figure 2).

TERMINOLOGY

Terminology for all plutonic rocks in the area follows that of Streckeisen (1976). For metamorphic rocks, mineral prefixes are listed in order of relative abundance, starting with least abundant first. Mineral abbreviations follow Kretz (1983). The following conventions are used regarding descriptive adjectives. A *gneissic granite* is a meta-igneous rock of granitic composition. A *granitic gneiss*, a *granite gneiss*, or a *gneiss of granitic composition* may be either a meta-igneous or a metasedimentary rock. Similarly, a *tonalitic gneiss* or a *tonalite gneiss* is a gneiss of tonalite modal composition, but may be of either meta-igneous or metasedimentary origin. A *gneissic meta-arkose* is a metasedimentary gneiss of overall granitic composition.

The term metamorphic grade is used in the case where bulk-rock composition or other factors prevent a more detailed assignment of metamorphic conditions. Where metamorphic conditions can be outlined more precisely, the metamorphic facies terminology of Turner (1981) is used.

Culshaw et al. (1988) introduced the concept of "gneiss associations" for mapping highly deformed and metamorphosed rocks of the Central Gneiss Belt. A "gneiss association" is an informal stratigraphic term that is primarily lithological, but which also may contain information with respect to plutonic history, metamorphism or mafic diking. If it were decided to formally name a "gneiss association" as a lithodemic unit under the North American Stratigraphic Code (NACSN 1983), in most cases, they would correspond to a suite or a complex.

Geology

PARAUTOCHTHON

Britt Domain (Units 1 to 14)

The Britt domain has a considerable range of protolith ages, including circa 1800 to 1600 Ma granitic orthogneiss cut by 1460 to 1430 Ma megacrystic granitoids (single cycle plutonic rocks). The polycyclic nature of the Britt domain is clearly shown by the following relationship that is very common in the older (1800-1600 Ma) group of gneisses: diabase dikes, deformed and metamorphosed in the Grenville orogenic cycle, cut circa 1450 Ma leucosomes (Culshaw et al. 1989, Ketchum et al. 1994). The metadiabase dikes have close affinities to the circa 1235 Ma northwest-striking Sudbury diabase dike swarm on the Laurentian foreland (Ketchum and Davidson 2000). The range of U-Pb crystallization ages as well as Nd model ages older than 1800 Ma (Dickin and McNutt 1989) clearly tie the gneisses to

undeformed rocks of comparable age in the US midcontinent (Easton 1986) and imply their Laurentian affinity (Culshaw et al. 1997; Carr et al. 2000).

In the map area several recognizable rock associations comprise the Britt domain: the Bustard Islands (unit 1), Key Harbour (units 2 to 5), Bayfield (units 6 to 8) and Nadeau Island (units 9 to 14) gneiss associations. All the aforementioned gneiss associations may represent separate phases in the evolution of an Andean-type arc and back-arc complex that formed at the southeastern continental margin of Laurentia in 2 distinct stages of crustal growth at 1800 to 1600 Ma and 1460 to 1430 Ma (Carr et al. 2000; Slagstad 2003). Understanding the detailed significance of these groupings awaits further work.

The most prominent member of the Bustard Islands gneiss association is a medium-grained, moderately foliated, migmatitic granodiorite-tonalite orthogneiss that contains many amphibolite lenses and layers, probably metamorphosed mafic dikes. The age of the orthogneiss is not known but the absence of a leucosome older than the dikes may imply a Mesoproterozoic age for the orthogneiss. This interpretation is supported by presence in the area (but not indicated on Map P.3548, back pocket) of lesser amounts of polycyclic gneiss with metadiabase dikes cutting older leucosomes.

The Key Harbour gneiss association is best exposed in the islands southwest of Key Harbour where all the compositional varieties are exposed. The most extensive unit is a pink migmatitic granite orthogneiss (unit 4) emplaced at circa 1690 Ma (Corrigan, Culshaw and Mortensen 1994). There are undated tonalitic orthogneiss and metasedimentary rocks that predate the granite. Mafic gneiss (metagabbro, monzodiorite)(unit 3), located south of Henvey Inlet to south of Byng Inlet, have been included in the Key Harbour gneiss association although contact relations are unknown. It is possible they are part of the Mesoproterozoic plutonic suite. Some metasedimentary rocks (unit 2) contain corundum, in addition to kyanite and sillimanite, as in the Nadeau Island gneiss association (see below). Along Highway 69 the Key Harbour gneiss association is represented by migmatitic layered grey gneisses of varied character (unit 5). These may be related to the older tonalitic gneisses present near Key Harbour. Monazite cooling ages of circa 1035 Ma (Corrigan, Culshaw and Mortensen 1994) are the best estimate for the age of Grenvillian upper amphibolite facies metamorphism.

The most voluminous member of the Bayfield gneiss association is a grey hornblende-bearing tonalitic orthogneiss (unit 7b). A granodiorite lacking hornblende, but commonly with recrystallised potassium feldspar megacrysts (unit 7a), is part of the same suite and locally (e.g., Meneilly Island) has patches partly retrogressed from granulite facies. Semi-pelitic and pelitic gneiss forms a mappable horizon (unit 6) in the south, otherwise the Bayfield gneiss association is poor in metasedimentary rocks. Pink leucocratic gneiss is a prominent member that is of potential supracrustal origin, and forms 2 large bodies, centred on Bayfield and along the margin of the Britt pluton. There are comparable bodies of pink leucocratic gneiss in most other domains along Georgian Bay and may represent one or more events common to all domains (Culshaw and Dostal 2002).

The Nadeau Island gneiss association has more lithological variation than the Bayfield gneiss association. The polycyclic orthogneiss in both gneiss associations are similar. There are, however, a greater number of mappable metsedimentary intervals in the Nadeau Island gneiss association, and small metasedimentary units (smaller than map scale) are common. In the north, close to Pointe-au-Baril channel, there are occurrences of corundum-bearing metasedimentary rocks in the Bayfield gneiss association. Small areas of preserved and partly retrogressed granulite facies rocks are relatively common throughout the gneiss association. Good examples occur along Highway 69 where, within tonalitic orthogneiss, mafic horizons contain relict orthopyroxene. Fresh mafic granulite occurs at Raspberry Island. The age of the Mesoproterozoic metamorphism, including formation of the mafic granulites, is estimated at 1450 to 1430 Ma (Tuccillo et al. 1992; Ketchum et al. 1998). Metasedimentary rocks

contain kyanite and sillimanite and Grenvillian metamorphic conditions are estimated at 700 to 800°C and 10 to 12 kbars (Ketchum et al. 1994)

The Britt domain is host to 2 intrusive complexes of Mesoproterozoic granitoid bodies. These bodies (unit 50) are sheet-like, commonly megacrystic, and have emplacement ages of 1460 to 1430 Ma (van Breemen et al. 1986; Corrigan, Culshaw and Mortensen 1994). In the Key Harbour gneiss association the intrusive complex is dominated by the monzogranitic Britt pluton, but includes granodiorite, granite, syenite and leucogabbro bodies. There are numerous small gabbroic bodies well exposed in the islands near Key Harbour, one of which is dated at greater than 1454 Ma (Davidson and van Breemen 2001), suggesting a potential link with the granitoid plutons. The Pointe-au-Baril intrusive complex lies within the Nadeau Island gneiss association. The Pointe-au-Baril intrusive complex is entirely granitoid, lacking the more extreme compositional varieties present near Key Harbour.

Pink leucocratic gneiss (unit 52), of the type found throughou the synthesis area, is present in the Britt domain both as mappable units and as outcrops that are too small to map. Along Highway 69, pink leucocratic rock demonstrably crosscuts pre-Grenvillian leucosome, but, for the most part, no clear age relationship is demonstrable between pink leucocratic gneiss and the surrounding rocks.

The major structural features of the Britt domain are large horizontal upright folds with southeast trending hinges. These folds generally deform an older Grenvillian fabric and have hinges parallel to a lineation that indicates the direction of maximum extension. Although the enveloping surfaces of the folds are gently dipping, the folds terminate in steep zones: for example, at the southeast margin of the Grenville Front tectonic zone (around the Bustard Islands) and at the southeastern extremity of the Britt Pluton, within the Bayfield gneiss association.

Lower Go Home Domain (Units 15 to 18)

The lower Go Home domain is dominated by Mesoproterozoic megacrystic granitoid rocks (circa 1460 Ma; T.E. Krogh, geochronologist, Jack Satterly Geochronology Laboratory, personal communication, 1991). These, together with coronitic gabbro bodies and numerous other, minor mafic bodies cut migmatitic granitoid gneisses that were likely emplaced at circa 1600 Ma (T.E. Krogh, geochronologist, Jack Satterly Geochronology Laboratory, personal communication, 1991). There are other units of unknown age, including strongly deformed metaplutonic rocks, as well as minor pelitic gneisses and thin, but laterally extensive, marbles (Culshaw et al. 1990, 1997). The presence of the Mesoproterozoic megacrystic granitoids cutting gneisses containing pre-granitoid leucosome is comparable to relative age relationships observed in the Britt domain and establishes the lower Go Home domain as part of the polycyclic, parautochthonous Laurentian craton (Culshaw et al. 1997; Carr et al. 2000).

The internal structure of the lower Go Home domain is marked by the presence of open, upright and subhorizontal folds of gneissosity comparable to folds in other domains. The boundary relations with overlying domains are complex. The boundary with the upper Go Home domain is marked by small (commonly metre-scale) anorthosite gneiss bodies and garnet amphibolite pods of similar size that are in places demonstrably retrogressed eclogites. Gneissosity above and below the boundary is concordant. The boundary of the Moon River subdomain and the lower Go Home domain is comparable, being marked by a continuous anorthosite sheet and several small (metre to centimetre scale) anorthosite bodies. In several locations gneissosity is discordant across the boundary. The 2 boundaries meet in a triple point on Highway 69, just south of the Moon River Bridge (see Map P.3551, back pocket), suggesting that the upper Go Home domain pinches out southeastward beneath the Moon River subdomain.

ALLOCHTHON

Shawanaga Domain (Units 19 to 24)

The Shawanaga domain along Georgian Bay consists of a large nappe formed of the metasupracrustal Sand Bay and metaplutonic Ojibway gneiss associations (Culshaw et al. 1989). The entire domain has been metamorphosed to upper amphibolite facies, at greater than 700°C and 10 to 12 kbar (Wodicka, Ketchum and Jamieson 2000). Deformation and high-grade polyphase metamorphism took place between about 1090 and 1050 Ma (Culshaw et al. 1997; Wodicka, Ketchum and Jamieson 2000; Slagstad 2003). Unlike the Parry Sound and Britt domains there are no crosscutting mafic dikes in the Shawanaga domain, but there are pods of retrogressed mafic eclogites of uncertain age (unit 54), and 1170 to 1150 Ma coronitic metagabbros (unit 53) (van Breemen and Davidson 1990).

The lower boundary of the Shawanaga domain, the Shawanaga shear zone, is a fundamental tectonic feature, straddling the boundary of the monocyclic Shawanaga domain with the polycyclic rocks of the Britt domain. The boundary, which can be precisely located on the islands of Georgian Bay, is the westernmost extension of the Grenville orogen-wide Allochthon Boundary Thrust. Structures related to thrusting are overprinted by extensional (top-to-the-southeast) deformation at circa 1020 Ma (Culshaw et al. 1994; Ketchum et al. 1998) along the Shawanaga shear zone, and the initial thrust sense is indirectly inferred from hanging wall – footwall relationships (e.g., high-pressure rocks are restricted to the hanging wall), although rare thrust-sense kinematic indicators are found inland from Georgian Bay (Culshaw et al. 1989, 1994, 1997). Extension accompanied formation of upright folds, with hinge lines parallel to the southeast-plunging stretching lineation (Culshaw et al. 1994). As with the correlative boundary in between the upper and lower Go Home domains, retrogressed gabbroic eclogite and metre-scale anorthosite blocks are locally associated with the Allochthon Boundary Thrust–Shawanaga shear zone.

SAND BAY GNEISS ASSOCIATION

The layered rocks of the Sand Bay gneiss association (Culshaw and Dostal 1997) include felsic supracrustal orthogneiss, amphibolite and metasedimentary rocks. Sand Bay metasedimentary rocks include quartzite, calc-silicate and semipelite. The semipelitic Dillon schist is a prominent marker unit that outlines the fold structure of the domain. Early Paleoproterozoic to circa 1400 Ma ages have been recorded from detrital zircons in a Sand Bay gneiss association quartzite (T.E. Krogh, geochronologist, Jack Satterly Geochronology Laboratory, personal communication, 2003). The Dillon schist has yielded zircon grains ranging from 1900±23 Ma to 1362±35 Ma, giving a maximum depositional age for the Sand Bay gneiss association protoliths of circa 1360 Ma (Culshaw and Dostal 1997). The felsic supracrustal orthogneisses are the most voluminous member. These are mostly pink, leucocratic, medium- to fine-grained, equigranular migmatitic rocks interpreted as metarhyolites. Grey, more plagioclase-rich intervals are also common. The best exposures of the Sand Bay gneiss association are along the west side of Killbear peninsula (within the provincial park) and on the shoreline of Shawanaga Bay where it is intersected by the syncline cored by Dillon Schist (the type section).

A geochemical study of the Sand Bay amphibolites and felsic orthogneisses suggested their protoliths were bimodal volcanic rocks (Culshaw and Dostal 1997; Slagstad 2003). The major and trace element geochemistry of the Sand Bay amphibolites resembles modern continental tholeiites, showing no significant metamorphic disruption of diagnostic trace elements, for example, the high field strength elements (Culshaw and Dostal 1997). The Sand Bay amphibolites have a prominent negative Nb anomaly suggesting involvement of subduction-modified mantle in their genesis. High Th/La in the Sand

Bay amphibolites compared to modern mid-ocean ridge basalts (MORB) indicate the possibility of minor crustal contamination. Sand Bay felsic orthogneisses have negative Eu, Ti and Nb anomalies compatible with a continental crustal or arc origin. The igneous protoliths may have originated in a continental environment undergoing active extension, perhaps a continental rift or continental arc-rift (back-arc or intra-arc) setting (Culshaw and Dostal 1997; Slagstad 2003).

OJIBWAY GNEISS ASSOCIATION

The Ojibway gneiss association is a 1466±11 Ma orthogneiss body of granodioritic-tonalitic composition with arc type granitoid geochemistry (T.E. Krogh, geochronologist, Jack Satterly Geochronology Laboratory, personal communication, 2003). The sheet-like Shawanaga pluton lies along the lower boundary of the Shawanaga domain. It is a circa 1460 Ma body of megacrystic garnet-amphibole-bearing granodiorite-granite (T.E. Krogh, geochronologist, Jack Satterly Geochronology Laboratory, personal communication, 2003). Compositional and age similarities between the Shawanaga pluton, Ojibway gneiss, and grey calc-alkaline gneisses from the Muskoka domain to the south led Slagstad (2003) to suggest that the Shawanaga pluton formed, along with the protoliths to the Ojibway and Muskoka gneiss associations, in a postulated circa 1450 Ma Ojibway–Muskoka arc. The Ojibway–Muskoka arc formed outboard of the Laurentian Britt domain, during the time that the latter underwent back-arc plutonism and 1450 to 1430 Ma granulite facies metamorphism (Ketchum et al. 1998).

Upper Go Home Domain (Units 25 to 29)

PINE ISLAND GNEISS ASSOCIATION

Leucosome-rich granitoid migmatite and pink leucocratic gneiss dominate the upper Go Home domain. Calc-silicate gneiss is a minor component. The upper Go Home domain resembles parts of the Shawanaga domain with respect to its tectonostratigraphic position and composition (e.g., migmatites of the Ojibway gneiss association). The age and details of geochemistry of this domain are unknown. As indicated above, the boundary with the lower Go Home domain is comparable to the lower boundary of the Shawanaga domain. It separates monocyclic from polycyclic rocks and is therefore interpreted to be the Allochthon-Parautochthon boundary thrust; however, unlike the Shawanaga shear zone, it is not overprinted by extensive extensional shear fabrics

PERE BREBEUF GNEISS ASSOCIATION

This is a unit of apparently uniform grey, migmatitic tonalitic and granodioritic gneiss. Information is scanty, but, on account of its uniformity and lack of associated rocks of definite supracrustal origin, it is interpreted as an orthogneiss of plutonic protolith. It is tentatively distinguished from the adjacent lower Go Home domain on account of lithological differences and because its boundaries, like those of the Pine Island gneiss association, are associated with anorthosite gneiss.

Parry Sound Domain (Units 30 to 41)

Several thrust-separated, lithologically distinctive subunits with different protolith ages comprise the Parry Sound domain. These are, from north to south, the predominantly supracrustal Lighthouse and Armer Bay gneiss associations which comprise the circa 1400 to 1330 Ma basal Parry Sound domain and

the mostly plutonic, circa 1400 to 1200 Ma, interior Parry Sound domain (van Breemen et al. 1986; Wodicka, Parrish and Jamieson 1996). The Parry Sound domain has experienced polyphase Grenvillian metamorphism including pervasive granulite facies metamorphism. An early episode of granulite facies Grenville metamorphism and deformation is recorded at 1160 to 1120 Ma, at least 40 million years before the beginning of any other Grenvillian metamorphism in the remainder of the Central Gneiss Belt (Culshaw et al. 1997). The allochthonous nature of the domain is demonstrated by the presence of granulite facies metamorphic assemblages and the presence of mafic dikes in most rock types, neither of which are present in the underlying Shawanaga or upper Go Home domains (Culshaw et al. 1989, 1997; Wodicka, Parrish and Jamieson 1996).

PARRY SOUND DOMAIN (BASAL)

The basal Parry Sound domain consists of the Lighthouse and Armer Bay gneiss associations. The Lighthouse gneiss association is thickest in the eastern part of Parry Island and severely thinned in the vicinity of Highway 69. Culshaw and Dostal (2002), working in the vicinity of Bateau Island (the western extremity of its outcrop), showed that the layered metamorphic rocks of the Lighthouse gneiss association, like the subjacent Sand Bay gneiss association, are of volcano-sedimentary origin. On Parry Island the supracrustal members are interlayered with a second grouping of supracrustal rocks (mostly quartzite) and tonalite-granodiorite orthogneiss that are cut by metamorphosed mafic dikes. The diked rocks are thus older than the volcano-sedimentary package and the interlayering of 2 gneiss associations must be tectonic in origin.

The volcano-sedimentary Lighthouse gneiss association is dominated by amphibolite and semipelitic to pelitic metasedimentary rocks divided, in the western study area of Culshaw and Dostal (2002), into geochemically and lithologically distinctive upper and lower units. The lower unit amphibolite has a basaltic tholeiite major element composition and a trace element signature resembling oceanic basalt with a minor subduction zone or subduction-modified mantle influence, similar to Sand Bay amphibolite geochemistry (Culshaw and Dostal 2002). The amphibolites of the upper unit have no negative Nb anomaly and have trace element ratios similar to mid-ocean ridge basalt (MORB); therefore, they are likely to have formed from the depleted mantle (Culshaw and Dostal 2002). This evidence and isotopic work in progress suggests the tectonic development of these rocks may be linked to that of both the Shawanaga and the Parry Sound domains. The age of the diked suite is constrained by the 1436±17 Ma age of the youngest detrital zircon in quartzite and the circa 1400 to 1330 Ma age of the orthogneisses (Wodicka, Parrish and Jamieson 1996). It shares detrital ages with parts of the Composite Arc Belt (better known as the Central Metasedimentary Belt; Carr et al. 2000) and the Adirondack Highlands (Wodicka, Parrish and Jamieson 1996). The Lighthouse gneiss association is best observed on the west side of Sandy Island (see Culshaw and Dostal (2002) for location of measured sections).

Para-amphibolites (unit 34) are the dominant member of the Armer Bay gneiss association, the thickest member of the basal Parry Sound assemblage on the mainland. It is distinguishable from the Lighthouse gneiss association by differences in the interlayered metasedimentary rocks (generally sulphide bearing in Armer Bay). The geochemistry and geochronology of this unit is unknown, but, on the basis of proximity and physical similarity, it is most likely similar in both aspects to the Lighthouse gneiss association.

The contact between the Armer Bay and Lighthouse can be directly observed along the shoreline at Parry Sound where gneissosity in the 2 units is conformable but evidently highly strained. This contact is therefore either primary, tectonic, or both.

The circa 1160 Ma (Wodicka, Parrish and Jamieson 1996) Parry Island anorthosite lies within the basal Parry Sound domain on Parry Island, and, presumably, anorthosite that underlies the offshore islands is part of this body. A circa 1350 Ma anorthosite (van Breemen et al. 1986) flanked by a young (lacking mafic dikes) megacrystic granitoid lies within the Armer Bay gneiss association on Parry Island and the mainland.

PARRY SOUND DOMAIN (INTERIOR)

The interior Parry Sound domain consists of Mesoproterozoic (circa 1400-1200 Ma) granulite facies metaplutonic rocks ranging from gabbro to granite, with subordinate metasedimentary rocks. The most important metaplutonic members appear to be intermediate in composition (spanning granodiorite-tonalite-quartz diorite). The overall range of orthogneiss compositions, from tonalitic, granitic and granodioritic gneiss to gabbro, suggests a calc-alkaline arc suite. Nd model ages of 1500 to 1400 Ma (Dickin and McNutt 1990) are close to crystallization ages and suggest these rocks formed from a juvenile source. Detailed petrography and geochemistry of these rocks are unknown. Metamorphosed mafic dikes cut all the rocks of the interior, further distinguishing them from rocks of the Shawanaga and upper Go Home domains.

The northwestern boundary of the Parry Sound domain interior with the underlying Armer Bay gneiss association is marked for most of its strike length by the Whitestone anorthosite. A northward transect along Highway 69 (or more lightly travelled roads parallel to it) affords a view of the progressive modification of the granulite facies L-S fabric typical of the interior of the domain through a wide zone of retrogression (not shown on maps), to development of linked shear zone systems and penetrative mylonite gneiss close to the boundary. Pegmatite bodies are very common along this transect and appear to be linked to extensional structures that deform the mylonitc fabrics.

This boundary is usually viewed as lying within the upper part of the Parry Sound shear zone (PSSZ), which may be thought of as a wide zone of elevated strain extending downward from top of the first shear zones within the interior Parry Sound domain to the top of the Shawanaga domain. Davidson and others (e.g., Davidson, Culshaw and Nadeau 1982; Culshaw, Davidson and Nadeau 1983; Davidson 1984a, 1984b) describe tectonites from several classic localities. This definition of the Parry Sound shear zone requires modification on Parry Island, where there are wide expanses from which the tectonites typical of the Parry Sound shear zone are absent. Moreover, a case can be made that tectonites considered typical of the Parry Sound shear zone are present within the Shawanaga domain well below the rocks normally thought of as lying within the Parry Sound shear zone thus bringing into question the location of a lower boundary to the Parry Sound shear zone. Whether or not the concept of a Parry Sound shear zone in terms of highly strained tectonites is useful as a first order tectonic feature, it seems clear that boundaries between allochthonous units are recognizable and persistent along strike and should be accorded due tectonic significance.

The southern boundary of the Parry Sound domain is problematic. This is in part because of uncertainty in precise knowledge of the protoliths at the boundary and in part because of the complex and unusual geometry of the boundaries. For example, there is field evidence that the protolith of parts of the Blackstone Lake gneiss association was a Parry Sound domain lithology. Secondly, the geometry of the boundary, as outlined by the map traces of the anorthosite sheets associated with the Twelve Mile Bay gneiss association and Moon River subdomain, is not easily explained. What can be stated, based on field observation, is that the approach to this boundary from the Parry Sound domain side is accompanied by progressive retrogression of the granulite facies assemblages. In this respect, at least, it resembles the boundary of the Parry Sound domain.

Moon River Subdomain (Units 42 to 46)

The Moon River subdomain consists of the Twelve Mile Bay, Moon River and Blackstone Lake gneiss associations. These lithological units, together with retrogressed gneisses in the south of the Parry Sound interior (southeast of the retrogression boundary) make up the system of late synforms referred to here as the Moon River structure. It is important to note that this structure consists of more than one lithologically defined domain and therefore postdates thrust stacking of the domains.

TWELVE MILE BAY GNEISS ASSOCIATION

The Twelve Mile Bay gneiss association (termed assemblage in some older publications) is a thin quartzite, pelite, semipelite and amphibolite unit (unit 44) dominated by 2 extensive sheets of anorthosite gneiss (unit 47) (Culshaw et al.1989). An age of less than 1130 Ma for the quartzite has been suggested based on zircon data (Wodicka, Parrish and Jamieson 1996). At its western end the Twelve Mile Bay gneiss association directly underlies the Parry Sound domain interior and it has been suggested to be physically continuous with the Lighthouse gneiss association of the basal portion of the Parry Sound domain, which it resembles (Culshaw et al. 1989). As indicated above, it has, however, a complex geometry: a lower anorthosite sheet extends southeastward at the contact of the base of the Moon River gneiss association with the Go Home domain. The upper anorthosite, together with the metasedimentary horizons diverges from the lower anorthosite, swinging northwest then northeast around the base of the Moon River gneiss association. This arm of the Twelve Mile Bay gneiss association becomes extremely attenuated (to centimetre thickness) along the northwestern and northeastern contact of the Moon River gneiss association.

MOON RIVER GNEISS ASSOCIATION

The Moon River gneiss association consists of rocks separated from subjacent units by extensions of the Twelve Mile Bay gneiss association. Prominent among the latter are the persistent horizons of anorthosite gneiss (unit 47). The most important members are uniform pink and grey, generally leucocratic and layered gneisses (unit 45 and 46) in which evidence for plutonic origin, such as deformed megacrysts, is lacking. Minor members include quartzite and para-amphibolite (unit 44). Given the textural nature of the major gneiss members, their similarity with leucocratic gneisses of the Sand Bay gneiss association and their association with minor but definitively metasupracrustal rocks, volcanic protoliths are plausible. However, this cannot be stated with certainty for all members mainly because the gneisses are very structurally evolved. The layered gneissosity that defines the Moon River synform also outlines a refolded nappe (van Berkel and Schwerdtner 1986) and locally can be shown to have been derived by transposition of an older gneissosity. Nd model ages (Dickin and McNutt 1989) demonstrate these rocks are juvenile crust. Small bodies of coronitic gabbro (unit 53) lie along the boundary.

BLACKSTONE LAKE GNEISS ASSOCIATION

Grey gneisses of granodioritic composition (unit 43b) together with pink leucocratic gneisses (unit 43a), similar to pink gneisses of other domains, are the chief components of the gneiss association. There is local evidence for derivation from Parry Sound rock types but the nature of protolith of the Blackstone Lake gneiss association remains in question. The Blackstone Lake gneiss association has a sheared boundary with local discordance against Parry Sound foliations beneath. A major point of uncertainty is the nature of the relationship of Blackstone rock types with retrogressed Parry Sound gneisses at the

southwestern extremity and southern boundary of the gneiss association. These are shown on the maps (P.3550 and P.3551, *see* back pocket) as sharp boundaries but these boundaries should be viewed with scepticism.

DISCUSSION

Cross Section of Central Gneiss Belt Along Georgian Bay: from Active Margin to Collisional Orogen

The restored cross section of the Central Gneiss Belt (Figure 3) illustrates some aspects of current views of its development. Before the Grenville Orogeny the future thrust sheets of the Central Gneiss Belt were arranged younging oceanward from cratonic Laurentia. The validity of this restoration is supported in that it also places units with similar, but distinctive minor plutonic units (e.g., anorthosite, coronitic gabbro) alongside one another (*see* Figure 3).

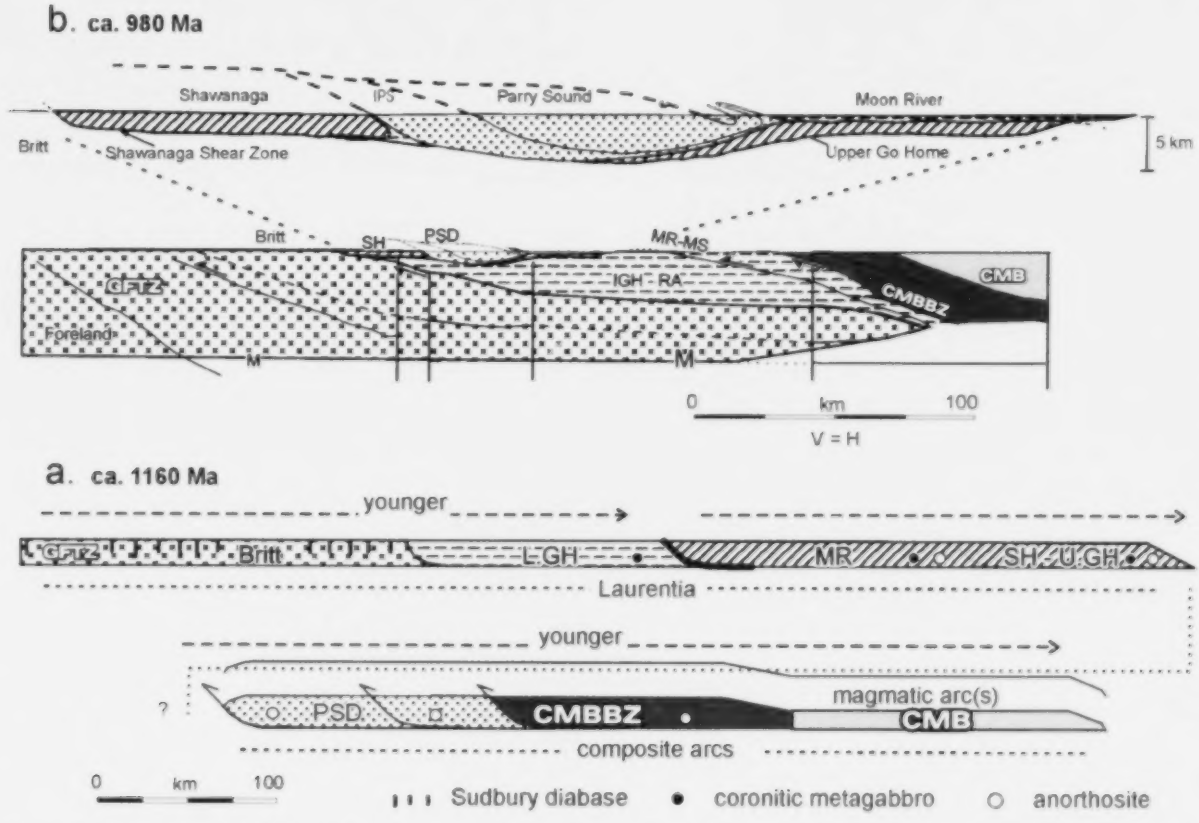

Figure 3. Cross section of the Central Gneiss Belt along Georgian Bay. Figure based on geology and seismic reflection profiles; sources can be found in Culshaw et al. (1997). **a.** postulated arrangement of domains before collision. **b.** postulated arrangement of domains after collision, convergence and mid-level crustal flow. Abbreviations: lPS, lower Parry Sound domain (now Parry Sound shear zone); GFTZ, Grenville Front tectonic zone; M, Moho; SH, Shawanaga domain; PSD, Parry Sound domain; lGH - RA, lower Go Home domain – Rosseau domain; MR–MS, Moon River domain–Muskoka domain; CMBBZ, Central Metasedimentary Belt boundary zone; CMB, Central Metasedimentary Belt; L.GH, lower Go Home domain; U.GH, upper Go Home domain.

ACTIVE MARGIN

The pre-Grenvillian configuration of the Laurentian margin was arrived at by successive magmatic additions to the periphery of a simple Andean-type margin. At first the arcs, being close to the craton, included considerable volumes of older Laurentian crust. These were later metamorphosed at ~1450 Ma and ultimately became the polycyclic domains of the Grenville Orogen. The proportion of older Laurentian crust diminishes and then vanishes in the younger, more outboard arcs. These are the monocyclic domains. This simple (suspiciously more simple than the Andes!) arrangement of arcs is complicated by the presence within the arcs of rock types indicating intra- or back-arc rifting or distal back-arc bimodal magmatism with significant A-type plutonism. For example, calc-alkaline arc rocks of Shawanaga domain are associated with amphibolites and felsic gneisses of the Sand Bay gneiss association interpreted to represent the magmatic products (basalts and rhyolites, respectively) of rifting of the same arc. Another example is given by the ~1450 Ma plutons of the Britt domain (e.g., Britt pluton) that are interpreted to have been emplaced far behind the active arc into an older arc. As these examples suggest, further complications to the simple oceanward-younging hypothesis will probably emerge as a result of future studies.

COLLISIONAL OROGEN

In the current model, the present configuration of the Central Gneiss Belt was derived from the oceanward-younging version of the Laurentian margin by classic forward-propagating thrusting with minimum out-of-sequence thrusting in combination with pervasive ductile flow. Although, the case for thrust-stacking can be made on the basis of lithostratigraphy alone, it has also been argued that most of the boundaries of the domains are discrete thrust-sense shear zones. They may have high-strain structures such as sheath folds, a variety of kinematic indicators and, in some cases, boundaries of overlying units truncating structures below.

However, a simple model based on foreland fold-and-thrust belts is clearly inappropriate. This is because most of the thrust-stacked domains, unlike high-level thrust sheets, consist of planar bodies of gneiss formed during one or more episodes of ductile flow that affected entire thrust sheets (Culshaw et al. 1997). The gneiss within the thrust sheet may comprise layered straight gneiss (often migmatitic) or leucosome-rich migmatite with a well-developed planar fabric and a variety of high-strain features (e.g., isoclinal folds). The elevated level of ductile deformation required to make such straight gneiss is demonstrated locally where strain gradients preserve different stages of its formation from original, sometimes irregularly shaped, compositional heterogeneities. Repetition of this level of deformation is shown where straight gneiss is transposed a second time (kneading) or folded by domain-scale nappes that are, in turn, refolded. That the conditions appropriate for such ductile flow persisted over a considerable period is shown by widespread upper amphibolite to granulite facies conditions and generation of migmatite and U/Pb ages that suggest high-grade metamorphism was attained more or less continuously for about 50 million years. Having established that thrust stacking and pervasive ductile flow of the thrust stack both took place, the question of the relative timing and nature of the relationship of the 2 phenomena remains. Did they occur simultaneously or were they separated in time?

Economic Geology

OVERVIEW

Little modern mineral exploration has been conducted within the Central Gniess Belt, in part because of the perception that high-grade gneiss terranes have little mineral potential. Lack of detailed geologic maps and mineral deposit models have also discouraged mineral exploration. Nevertheless, our understanding of the tectonic architecture of the region allows establishment of a broad framework for mineral exploration within the Central Gneiss Belt (see also Easton and Fyon 1992). For example, flagstone is a major commodity that is not domain specific, as the best flagstone prospects are found in transposed and straight gneiss zones associated with terrane or domain boundaries. Also associated with terrane or domain boundaries are circa 1170 million-year-old mafic and ultramafic bodies (metabasites and pseudoecologites) which have recently been explored for platinum group element, copper and gold mineralization (Garland and Villard 1990).

MINERAL OCCURRENCES

Maps P.3548 to P.3552 (*see* back pocket) include all known metallic and nonmetallic Mineral Deposit Inventory (MDI) occurrences within the study area. Examination of specific mineral occurrences and prospects was not a focus of the study or the mapping program. With few exceptions, the MDI occurrences are localized into 5 geographic groups.

1. Occurrences near Britt Station (*see* Map P.3548) associated with pegmatite veins in or adjacent to the Still River gneiss association (unit 5). These occurrences have been examined for feldspar, uranium, rare elements, and columbite. To date, no significant mineralization has been found.
2. Occurrences located within the interior of Parry Sound domain (*see* Maps P.3550 and P.3551). Villard, Keevil and Hogg (1984) summarized these occurrences, many of which may contain minor amounts of gold. Most are associated with quartz veins, and contain varied amounts of chalcopyrite, pyrite and pyrrhotite, which are generally the minerals reported in MDI. The veins are spatially associated with metamorphosed quartz diorite bodies surrounded by mafic gneisses.
3. Occurrences of flagstone producing and past-producing quarries in the Parry Sound shear zone (*see* Map. P.3350). Marmont (1991) summarized the flagstone potential within the western Central Gneiss Belt of Ontario.
4. Occurrences located east of Blackstone Lake and near Mactier (*see* Map. P.3551) are associated with pegmatite veins hosted by leucogneiss (unit 43) of the Blackstone Lake gneiss association, in close proximity to mafic rocks of the anorthosite suite (unit 47). These occurrences were examined for feldspar, uranium, rare elements, and columbite between 1910 and 1925 (Hewitt 1967). To date, no significant mineralization has been found. Proximity to the Canadian Pacific railway right-of-way was probably a major factor in the initial examination of these occurrences.
5. Occurrences in the vicinity of Six Mile Lake Provincial Park (*see* Map P.3552) that are associated with rusty schists and marble horizons in the Honey Harbour gneiss association of the lower Go Home domain. Mineralization consists of graphite and minor gold and sulphide occurrences. Easton (1995) describes these occurrences, including several not included within MDI.

MINERAL POTENTIAL

Parautochthon

Few mineral occurrences have been reported from rocks of the parautochthon. The polycyclic character of the rocks present in the parautochthon, in conjunction with the abundance of felsic, moncyclic plutonic rocks, suggests that this part of the study area has limited mineral potential. The exception to this assessment may be the metasedimentary rocks of the lower Go Home domain, which host minor graphite, gold and sulphide occurrences (Easton 1995).

Allochthon

Apart from the Parry Sound domain, which is described below, few mineral occurrences have been reported from rocks of the allochthon. The presence of metasedimentary rocks within much of Shawanaga domain, as well as the presence of both mafic and felsic metavolcanic rocks of continental affinity in this domain (Culshaw and Dostal 1997, 2002) suggest that Shawanga domain might have a higher mineral potential than previously thought. Commodities of interest are volcanogenic massive sulphide deposits (VMS) and sedimentary-hosted (SEDEX) base metal deposits.

PARRY SOUND DOMAIN

The abundance of mafic rocks and carbonate and pelitic gneisses in the Parry Sound domain makes this region the most extensively prospected and the best exploration target in the Central Gneiss Belt. Villard, Keevil and Hogg (1984) summarized the numerous gold prospects in the area. Most are associated with quartz veins, and contain associated chalcopyrite, pyrite and pyrrhotite, and are spati associated with metamorphosed quartz diorite bodies surrounded by mafic gneisses. Two vein types are documented: (1) copper-gold-bearing veins in gabbroic rocks in mafic gneiss; and (2) copper-nickel- and copper-zinc-bearing veins in the contact zone between felsic and mafic gneiss. Minor past production was achieved from a few deposits (Satterly 1943; Garland and Villard 1990). Northeast of the study area, small bodies of massive magnetite occur in Lount Township within garnet-hornblende gneiss and may represent disaggregated or disrupted iron formation (Easton and Fyon 1992).

The industrial mineral potential of the Parry Sound domain is high, and includes alumina sources (mainly meta-anorthosite; Marmont 1988a), agricultural lime from marbles (Marmont 1988b), building stone (Marmont 1991) and flagstone (Fouts and Marmont 1989). The best flagstone quarries are located in the Parry Sound shear zone.

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Appendix 1.

Listing of Published Geochronological Data for the Study Area.

Appendix 1. Listing of published geochronological data for the study area.

Mineral	Decay System	Age, in Ma	Error, in Ma	Reference	Comment
				31D13, Penetanguishene	
z	U	1047	2	Bussy et al. 1995	#4, Go home domain, age of regional metamorphism
z	U	1469	11	Ketchum and Krogh 1997	Go Home domain, pseudoeclogite, upper intercept, crystallization age
z	U	1089	2	Ketchum and Krogh 1997	Go Home domain, pseudoeclogite, lower intercept, metamorphic age
				31E4, Lake St. Joseph	
u	W	984		Stockwell 1982	Blackstone Lake, $^{207}Pb/^{206}Pb$ near concordant minimum
u	W	976		Wasserburg & Hayden 1955	Blackstone Lake, $^{07}Pb/^{206}Pb$, minimum
k	K	985	40	Wasserburg and Hayden 1955	Blackstone Lake
m	K	995	60	Lowdon 1960	GSC 59-45
m	K	940	60	Lowdon 1960	GSC 59-44
u	W	976		Cumming et al. 1955	Conger Twp, $^{07}Pb/^{206}Pb$ near concordant minimum
k	K	761	70	Cumming et al. 1955	Tor 1223A
b	K	839	80	Cumming et al. 1955	Tor 1224A
m	A	860	3	Cosca 1989	PS86B-1B, plateau age
				41H1, Sans Souci	
z	U	1300	+17/-25	Wodicka, Parrish and Jamieson 1996	90N213, tonalite, Paleoproterozoic inheritance at ~1660 and ~2270Ma
z	U	1317	24	Wodicka, Parrish and Jamieson 1996	90N202, tonalite, interior Parry Sound domain, same age as the McKellar gneiss (1326 as recalculated from van Breemen et al. 1986)
z	U	1163	3	Wodicka, Parrish and Jamieson 1996	90N210, crystallization age, Parry Island anorthosite
z	U	1151	1	Wodicka, Parrish and Jamieson 1996	89N153c, dike cutting Parry Island anorthosite, minimum age of crystallization and time of metamorphism
z	U	<1121	4	Wodicka, Parrish and Jamieson 1996	90N205c, 12 Mile Bay quartzite, youngest single grain
				41H7 and 41H8, Parry Sound	
z	U	1350	50	van Breemen et al. 1986	Whitestone anorthosite near Mill Lake, Geology of Ontario #321
z	U	1346	+69/-39	van Breemen et al. 1986	Nobel gneiss (marginal orthogneiss), Geology of Ontario #323
w	R	1330	44	Connare & McNutt 1985	Nobel gneiss, n=?, Isr=0.7033/17, MSWD=1.67
z	U	1159	+5/-4	van Breemen et al. 1986	1159+5/-4, syntectonic pegmatite, Parry Sound shear zone
z	U	1377	14	Wodicka, Parrish and Jamieson 1996	Isabella Island granite gneiss, cuts Whitestone anorthosite, upper limit for igneous crystallization
z	U	1160	Circa	Wodicka, Parrish and Jamieson 1996	89N104, Isabella Island granite gneiss, time of regional metamorphism
z	U	1382	30	Wodicka, Parrish and Jamieson 1996	88N36c, megacrystic granite, best estimate of emplacement age, mimimum age of 1361+/-9 Ma, metamorphism at 1160 Ma
w	R	1145		Krogh and Davis 1969	#13, n=2
z	U	1042	4	Ketchum et al. 1998	91-270, pre-kinematic dike cutting Pointe-au-Baril complex, in Shawanaga shear zone
z	U	1019	4	Ketchum et al. 1998	91-267a, late syn-kinematic dike cutting Pointe-au-Baril complex, in Shawanaga shear zone
z	U	988	2	Ketchum et al. 1998	91-269, post-kinematic dike cutting Pointe-au-Baril complex, in Shawanaga shear zone
t	U	1045		Ketchum et al. 1998	LH89-11-2, $^{07}Pb/^{206}Pb$ age
t	U	1026		Ketchum et al. 1998	LH89-11-1, $^{07}Pb/^{206}Pb$ age
t	U	967		Ketchum et al. 1998	DS-1-2, $^{07}Pb/^{206}Pb$ age
t	U	956		Ketchum et al. 1998	DS-1-1, $^{07}Pb/^{206}Pb$ age
t	U	1058	2	Tuccillo et al. 1992	91-16
m	A	897	4	Cosca 1989	PSA-1, plateau
b	A	926	4	Cosca 1989	PSA-2, plateau
m	A	894	3	Cosca 1989	PS86B-9, plateau
m	A	889	3	Cosca 1989	PS86B-14B, plateau
m	A	903	3	Cosca 1989	PS86B-16C, plateau

Appendix 1. Listing of published geochronological data for the study area - continued.

Mineral	Decay System	Age, in Ma	Error, in Ma	Reference	Comment
				41H7 and 41H8, Parry Sound	
m	A	909	3	Cosca 1989	PSI-861, plateau
b	A	1126	2	Cosca 1989	PSI-861, total gas, excess argon, in Parry Sound shear zone
h	A	969	5	Culshaw, Reynolds and Check 1991	#6
b	A	943	5	Culshaw, Reynolds and Check 1991	#6
m	A	905	3	Culshaw, Reynolds and Check 1991	#7
m	A	888	8	Reynolds et al. 1995	#10
m	A	899	6	Reynolds et al. 1995	#11
m	A	884	10	Reynolds et al. 1995	#12
m	A	891	8	Reynolds et al. 1995	#13
z	U	1121	12	Ketchum and Krogh 1997	Frederic Inlet pseudoecologite, Twin Doves Island, upper intercept, metamorphic age
z	U	1001	4	Ketchum and Krogh 1997	Frederic Inlet pseudoecologite, Twin Doves Island, lower intercept, metamorphic age
z	U	1095		Ketchum and Krogh 1997	Frederic Inlet pseudoecologite, Hooper Island, metamorphic age
z	U	1091	11	Ketchum and Krogh 1997	Frederic Inlet pseudoecologite, King Bay, metamorphic age
z	U	1114	2	Bussy et al. 1995	#1, dike cuts early metamorphic fabric in Parry Sound domain
z	U	<1385	4	Wodicka, Parrish and Jamieson 1996	88N39b, Parry Sound assemblage quartzite, youngest grain, maximum age of deposition
				41H9 and 41H10, Naiscoot	
w	R	1752	95	Krogh & Davis 1969, 1970a, 1970b, 1971b	Pointe-au-Baril, #11, n=10, Isr=0.7016
z	U	1457	+8/-6	van Breemen et al. 1986	Britt pluton emplacement, Geology of Ontario #320
t	U	1430	17	Ketchum et al. 1998	GC89-117, tonalite phase of Pointe-au-Baril complex, upper intercept
t	U	998	15	Ketchum et al. 1998	GC89-117, tonalite phase of Pointe-au-Baril complex, lower intercept
t	U	1049		Ketchum et al. 1998	TK84-92-1, $^{07}Pb/^{206}Pb$, also 985 & 961 Ma fractions, older metamorphism
t	U	985		Ketchum et al. 1998	TK84-92-1, $^{07}Pb/^{206}Pb$ age
t	U	961		Ketchum et al. 1998	TK84-92-1, $^{07}Pb/^{206}Pb$ age
t	U	1028		Ketchum et al. 1998	GC89-128-1, $^{07}Pb/^{206}Pb$ age
t	U	1024		Ketchum et al. 1998	GC89-119-2, $^{07}Pb/^{206}Pb$ age
t	U	1005		Ketchum et al. 1998	GC89-119-1, $^{07}Pb/^{206}Pb$ age
t	U	1004		Ketchum et al. 1998	GC89-118-1, $^{07}Pb/^{206}Pb$ age
t	U	1000		Ketchum et al. 1998	GC89-118-1, $^{07}Pb/^{206}Pb$ age
t	U	1000		Ketchum et al. 1998	GC89-122-1, $^{07}Pb/^{206}Pb$ age
t	U	958		Ketchum et al. 1998	GC89-123-1, $^{07}Pb/^{206}Pb$ age
t	U	1022		Ketchum et al. 1998	GC89-124-1, $^{07}Pb/^{206}Pb$ age
t	U	1018		Ketchum et al. 1998	DS-3-1, $^{07}Pb/^{206}Pb$ age
t	U	1008		Ketchum et al. 1998	DS-4-1, $^{07}Pb/^{206}Pb$ age
t	U	966		Ketchum et al. 1998	GC89-127-1, $^{07}Pb/^{206}Pb$ age
z	U	1452	2	Ketchum et al. 1994	89-37a, mafic granulite, dates granulite facies metamorphism in Britt domain
z	U	1448	1	Ketchum et al. 1994	91-266, leucosome in mafic granulite, dates granulite facies metamorphism in Britt domain at 1448 to 1452 Ma
t	U	1078	4	Tuccillo et al. 1992	91-18, in Parry Sound shear zone
g	U	1123	3	Tuccillo et al. 1992	PS88-1, garnet, in Parry Sound shear zone
g	U	1396	6	Tuccillo et al. 1992	SH88-7b, garnet, Britt domain
m	U	1053	2	Tuccillo et al. 1992	SH88-7b/1, Britt domain
m	U	1062	2	Tuccillo et al. 1992	SH88-7b/2, Britt domain
a	U	1435	2	Tuccillo et al. 1992	SH88-58/1a, allanite, Britt domain
a	U	1450	1	Tuccillo et al. 1992	SH88-58/2a, allanite, Britt domain
h	A	974	5	Culshaw, Reynolds and Check 1991	#4, Britt pluton

Appendix 1. Listing of published geochronological data for the study area - continued.

Mineral	Decay System	Age, in Ma	Error, in Ma	Reference	Comment
				41H9 and 41H10, Naiscoot	
h	A	964	5	Culshaw, Reynolds and Check 1991	#5, Shawanaga pluton
b	A	948	5	Culshaw, Reynolds and Check 1991	#5, Shawanaga pluton
m	A	904	3	Culshaw, Reynolds and Check 1991	#5, Shawanaga pluton
m	A	904	6	Reynolds et al. 1995	#50
m	A	899	6	Reynolds et al. 1995	#60
m	A	896	6	Reynolds et al. 1995	#70
d	U	1152	2	Heaman and LeCheminant 1993	coronitic metagabbro, see also van Breemen and Davidson 1990
z	U	1050		Heaman and LeCheminant 1993	coronitic metagabbro, see also van Breemen and Davidson 1990
z	U	* 1460	+12/-8	Krogh (unpubublished) cited in Ketchum et al. 1998	Pointe-au-Baril complex granite, no location specified
z	U	* 1457	+10/-11	Ketchum et al. 1998	inherited zircon in pegmatite (GC91-267a,GC91-269,GC91-270) cutting Pointe-au-Baril complex, upper intercept, no single location
z	U	* ~1063		Ketchum et al. 1998	Near concordant overgrowths on inherited zircons in pegmatite, dates regional metamorphism, no single location
				41H15, Key Harbour	
z	U	1467	+11/-7	Davidson and van Breemen 1994	Kings Island pluton, near Grenville Front tectonic zone--Britt domain boundary, similar age to Britt pluton
u	W	1043		Lowdon 1961	Besner Mine, $^{207}Pb/^{206}Pb$ near concordant minimum
u	W	875		Cumming et al. 1955	Besner Mine, $^{207}Pb/^{206}Pb$ near concordant maximum
d	U	>1454		Davidson and van Breemen 2001	87DM34, 3 discordant grains yield minimum age, $^{07}Pb/^{206}Pb$ ages of 1287, 1343 and 1454 Ma
z	U	1013	2	Davidson & van Breemen 2001	87DM34, zircon fraction, $^{07}Pb/^{206}Pb$ age
z	U	1684	8	Corrigan, Culshaw and Mortensen 1994	#1, upper intercept, Key Harbour granite
z	U	1146	$^{+137}_{-128}$	Corrigan, Culshaw and Mortensen 1994	#1, lower intercept, Key Harbour granite
z	U	1442	+7/-6	Corrigan, Culshaw and Mortensen 1994	#2, upper intercept, Mann Island granodiorite
z	U	945	+47/-48	Corrigan, Culshaw and Mortensen 1994	#2, lower intercept, Mann Island granodiorite
t	U	972	7	Corrigan, Culshaw and Mortensen 1994	#2, Mann Island granodiorite, $^{07}Pb/^{206}Pb$ age
n	U	1035	1	Corrigan, Culshaw and Mortensen 1994	#3, peak M3 metamorphism, cooling through 725°C
z	U	1456	12	Corrigan, Culshaw and Mortensen 1994	#4, upper intercept, time of leucosome formation
t	U	1015	16	Corrigan, Culshaw and Mortensen 1994	#4, lower intercept, time of post-metamorphic cooling
t	U	990	2	Corrigan, Culshaw and Mortensen 1994	#5, age of dike emplacement
t	U	~980		Corrigan, Culshaw and Mortensen 1994	#6, granodiorite similar to Mann Island granodiorite, similar titanite age to Mann Island granodiorite
h	A	968	5	Culshaw, Reynolds and Check 1991	#1, Britt pluton
b	A	978	6	Culshaw, Reynolds and Check 1991	#1, Britt pluton
m	A	924	3	Culshaw, Reynolds and Check 1991	#1, Britt pluton
k	A	902	6	Culshaw, Reynolds and Check 1991	#1, Britt pluton
b	A	993	5	Culshaw, Reynolds and Check 1991	#2, Britt pluton
m	A	922	3	Culshaw, Reynolds and Check 1991	#2, Britt pluton
h	A	967	7	Culshaw, Reynolds and Check 1991	#3, Britt pluton
b	A	1004	6	Culshaw, Reynolds and Check 1991	#3, Britt pluton, excess argon?
h	A	1020	5	Reynolds et al. 1995	#102, plateau, eastern Grenville Front tectonic zone
k	A	917	8	Reynolds et al. 1995	#102, plateau, eastern Grenville Front tectonic zone
h	A	991	5	Reynolds et al. 1995	#103, plateau, eastern Grenville Front tectonic zone
k	A	980	8	Reynolds et al. 1995	#103, plateau, eastern Grenville Front tectonic zone
h	A	992	8	Reynolds et al. 1995	#33, plateau, eastern Grenville Front tectonic zone
k	A	936	8	Reynolds et al. 1995	#33, plateau, eastern Grenville Front tectonic zone
m	A	931	7	Reynolds et al. 1995	#38, plateau
h	A	1005	8	Reynolds et al. 1995	#118, plateau

Appendix 1. Listing of published geochronological data for the study area - continued.

Mineral	Decay System	Age, in Ma	Error, in Ma	Reference	Comment
				41H9 and 41H10, Naiscoot	
k	A	929		Reynolds et al. 1995	#118
h	A	998	8	Reynolds et al. 1995	#49
m	A	934	7	Reynolds et al. 1995	#49
k	A	922	8	Reynolds et al. 1995	#49
h	A	990	5	Reynolds et al. 1995	#107
m	A	932	7	Reynolds et al. 1995	#108
m	A	903	9	Reynolds et al. 1995	#1a
m	A	904	8	Reynolds et al. 1995	#40
k	K	835	50	Lowdon 1960, 1961	GSC 59-47
b	K	779	50	Lowdon 1960, 1961	GSC 59-46

Mineral abbreviations: a = allanite, b = biotite, d = baddeleyite, g = garnet, h = hornblende, k = potassium feldspar, m = muscovite, n = monazite, t = titanite, u = uranitinite, w = whole rock, z = zircon. **Decay system abbreviations:** A = $^{40}Ar/^{39}Ar$, K = K/Ar, R = Rb/Sr, U = U/Pb, W = Pb/Pb.

All ages are plotted on maps P.3548 through P.3552, except for ages with an * appearing before the age. In these cases, no specific location was available, or the ages reported are composites from several sample sites.

Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 023	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 90**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

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